Data Communications and Networking Fourth Edition

Forouzan

Chapter 12

Multiple Access

Figure 12.1 *Data link layer divided into two functionality-oriented sublayers*

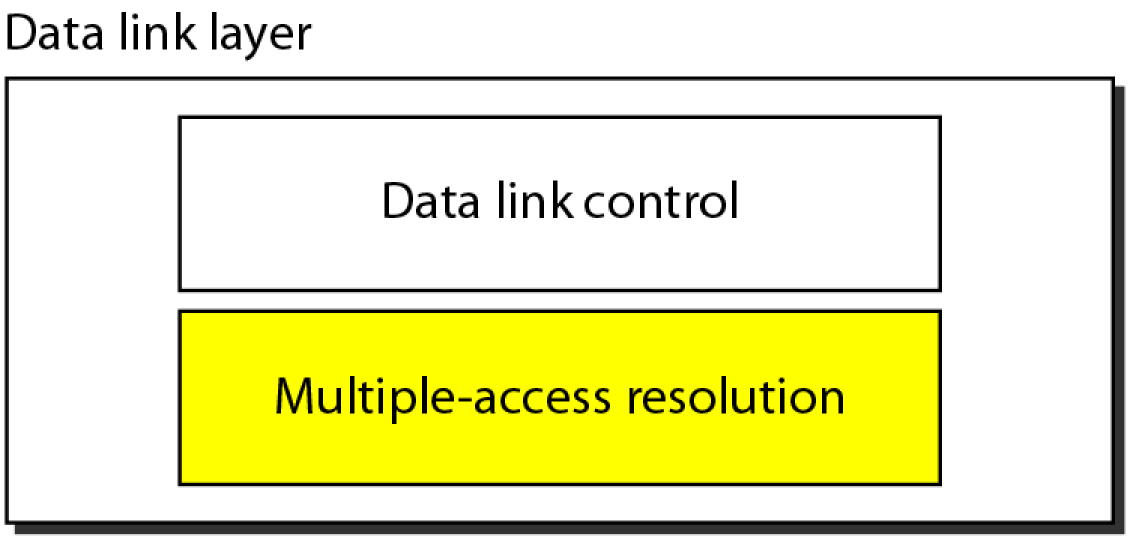
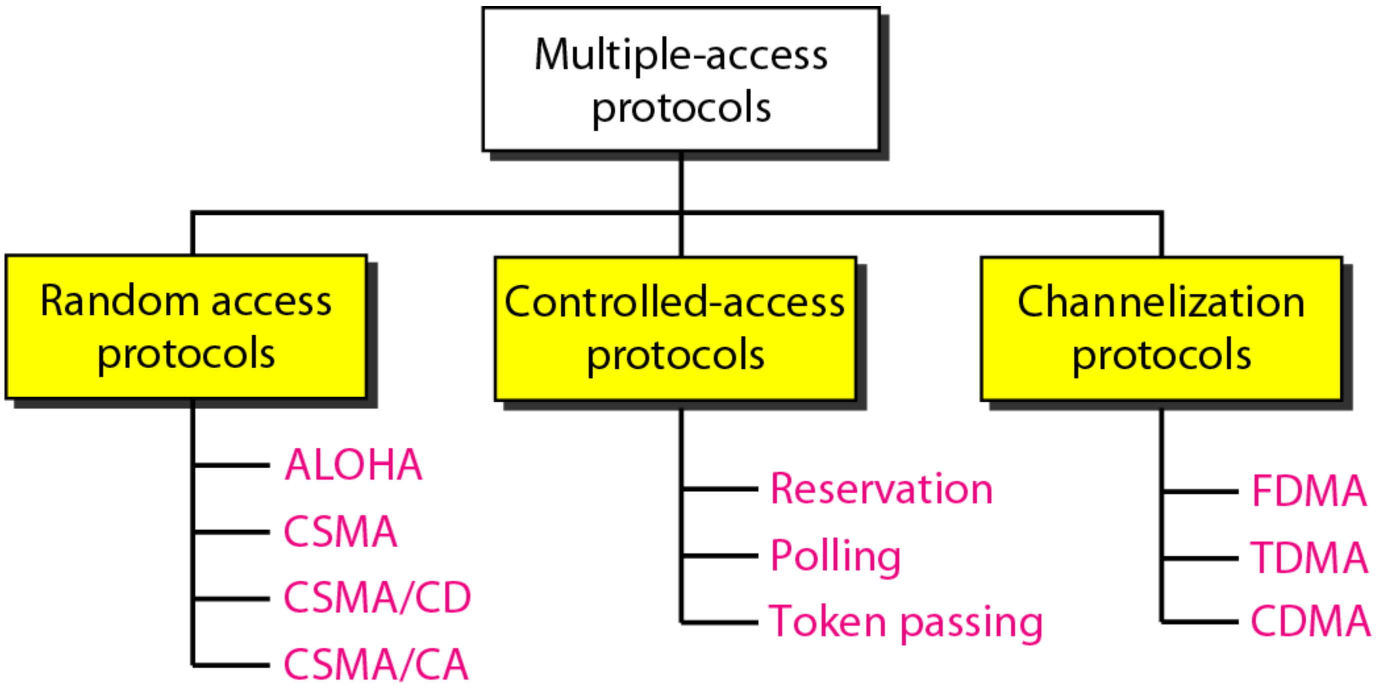


Figure 12.2 *Taxonomy of multiple-access protocols discussed in this chapter*



12-1 RANDOM ACCESS

In random access or contention methods, no station is superior to another station and none is assigned the control over another. No station permits, or does not permit, another station to send. At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.

Random access is based on two features:

1. *There is no scheduled time for a station to transmit.*
2. *Transmission is random among the stations*

To avoid access conflicts (collisions), a station must answer

1. *When can the station access the medium?*
2. *What can the station do if the medium is busy ?*
3. *How can the station determine the success or failure of the transmission?*
4. *What can the station do if there is an access conflict?*

RANDOM ACCESS protocols

ALOHA
Carrier Sense Multiple Access
Carrier Sense Multiple Access with Collision Detection
Carrier Sense Multiple Access with Collision Avoidance

ALOHA: (Pure ALOHA and Slotted ALOHA)

Pure ALOHA : The idea is to send a frame whenever a station has a frame to send.

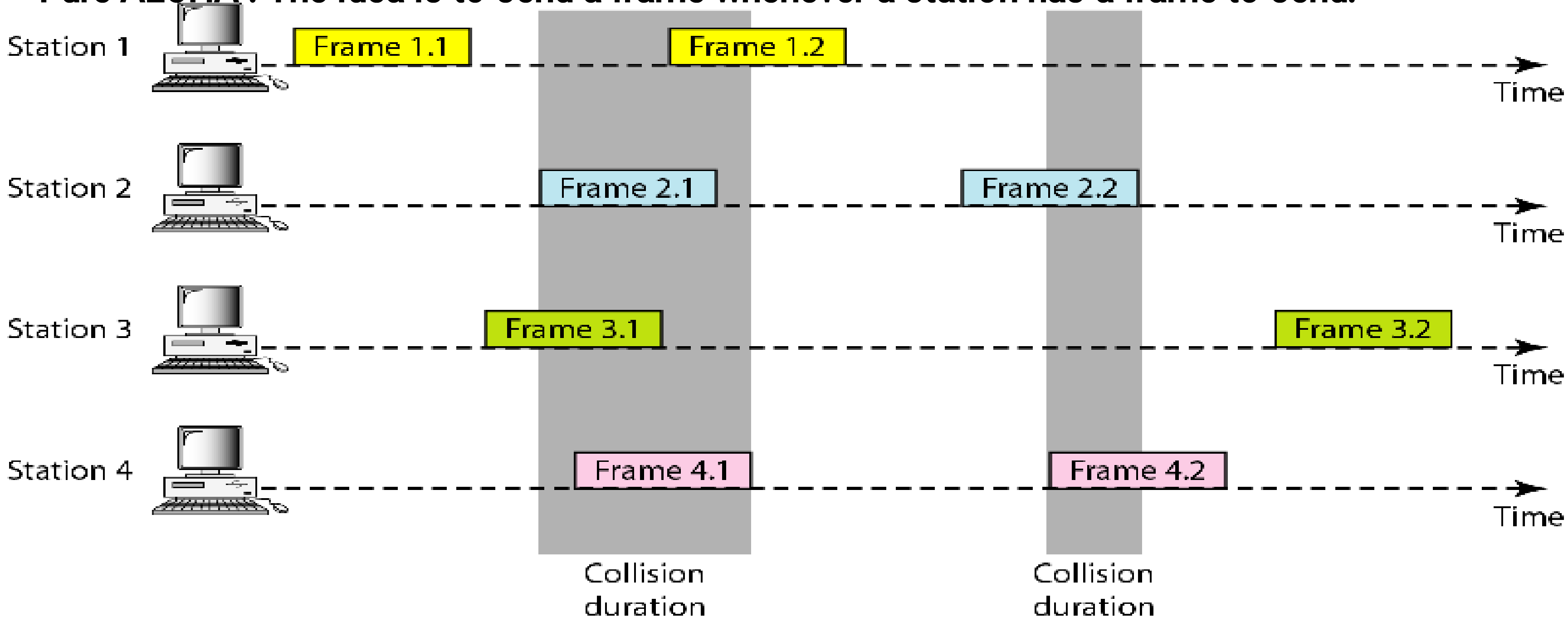
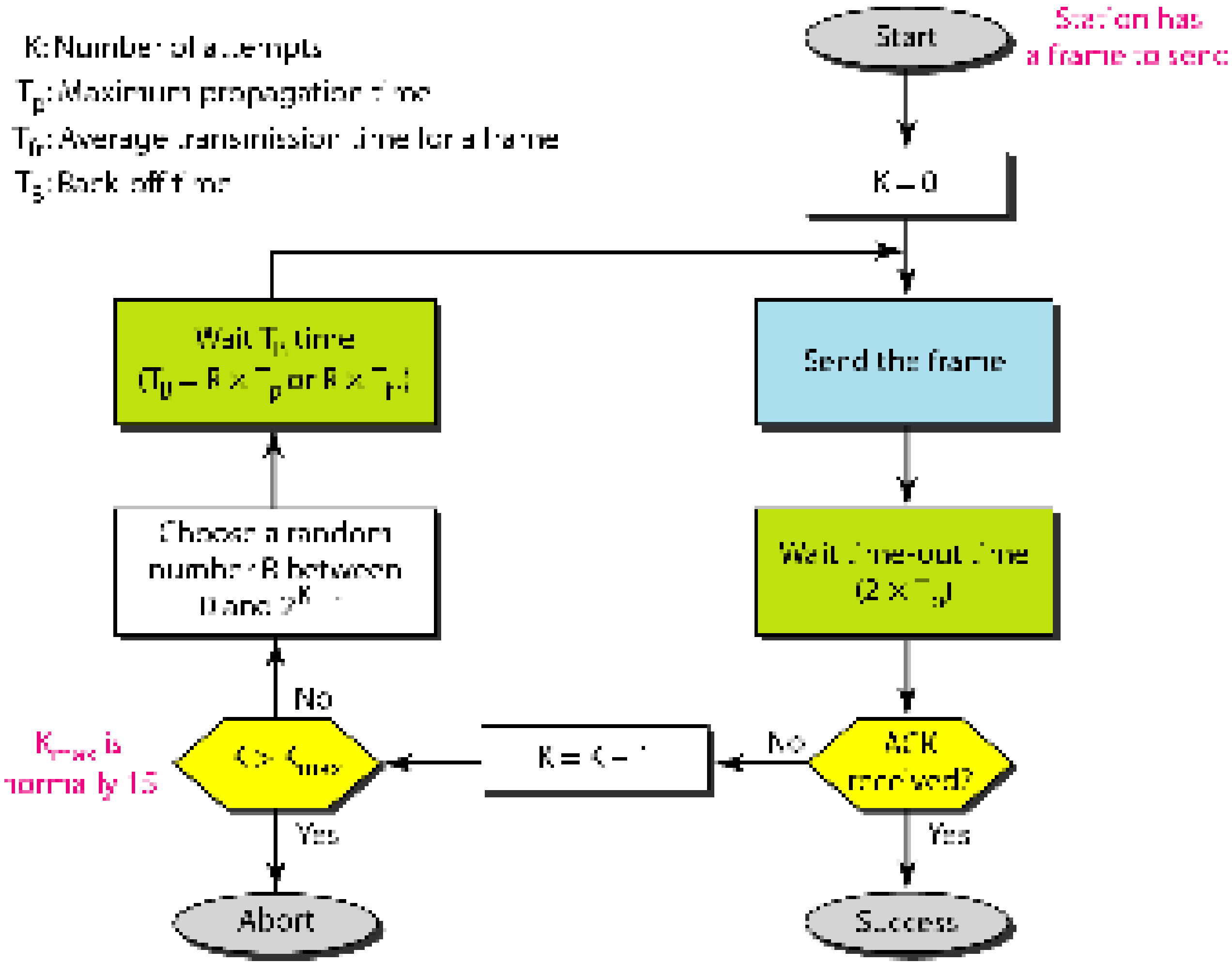


Figure 12.4 *Procedure for pure ALOHA protocol*



Example 12.1

The stations on a wireless ALOHA network are a maximum of 600 km apart. If we assume that signals propagate at 3×10^8 m/s, we find

$$T_p = (600 \times 10^5) / (3 \times 10^8) = 2 \text{ ms.}$$

Now we can find the value of T_B for different values of K.

a. For $K = 1$, the range is $\{0, 1\}$. The station needs to| generate a random number with a value of 0 or 1. This means that T_B is either 0 ms (0×2) or 2 ms (1×2), based on the outcome of the random variable.

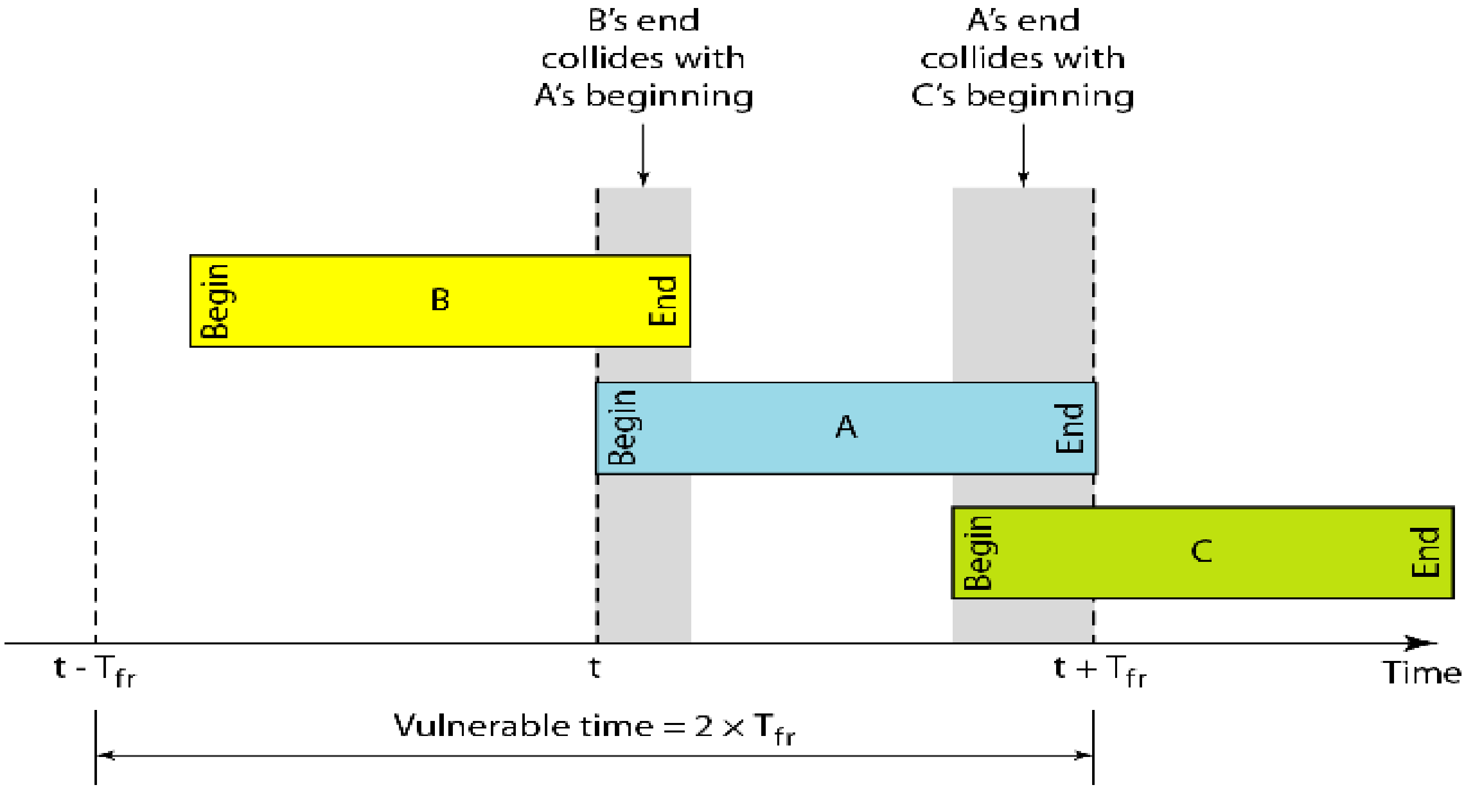
Example 12.1 (continued)

b. For K = 2, the range is {0, 1, 2, 3}. This means that T_B can be 0, 2, 4, or 6 ms, based on the outcome of the random variable.

c. For K = 3, the range is {0, 1, 2, 3, 4, 5, 6, 7}. This means that T_B can be 0, 2, 4, . . . , 14 ms, based on the outcome of the random variable.

d. We need to mention that if K > 10, it is normally set to 10.

Vulnerable time for pure ALOHA protocol



Vulnerable time for pure ALOHA : 2 X Tfr

 Figure 12.5 *Vulnerable time for pure ALOHA protocol*

Example 12.2

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the requirement to make this frame collision-free?

Solution

Average frame transmission time T_{fr} is 200 bits/200 kbps or 1 ms. The vulnerable time is 2×1 ms = 2 ms. This means no station should send later than 1 ms before this station starts transmission and no station should start sending during the one 1-ms period that this station is sending.

Throughput for pure ALOHA protocol

- It can be proved that the average number of successful transmissions : $S = G \times e^{-2G}$

where

G→ Average number of frame generated by the system during one frame transmission time.

The maximum throughput S_{max} ▪ 0.184 when G▪1/2; (18.4 %)

Note

The throughput for pure ALOHA is

$$S = G \times e^{-2G}.$$

The maximum throughput

$S_{max} = 0.184$ when G= (1/2).

Example 12.3

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces
a. 1000 frames per second b. 500 frames per second
c. 250 frames per second

Solution

The frame transmission time is 200/200 kbps or 1 ms.
a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ or $S = 0.135$ (13.5 percent). This means that the throughput is $1000 \times 0.135 = 135$ frames. Only 135 frames out of 1000 will probably survive.

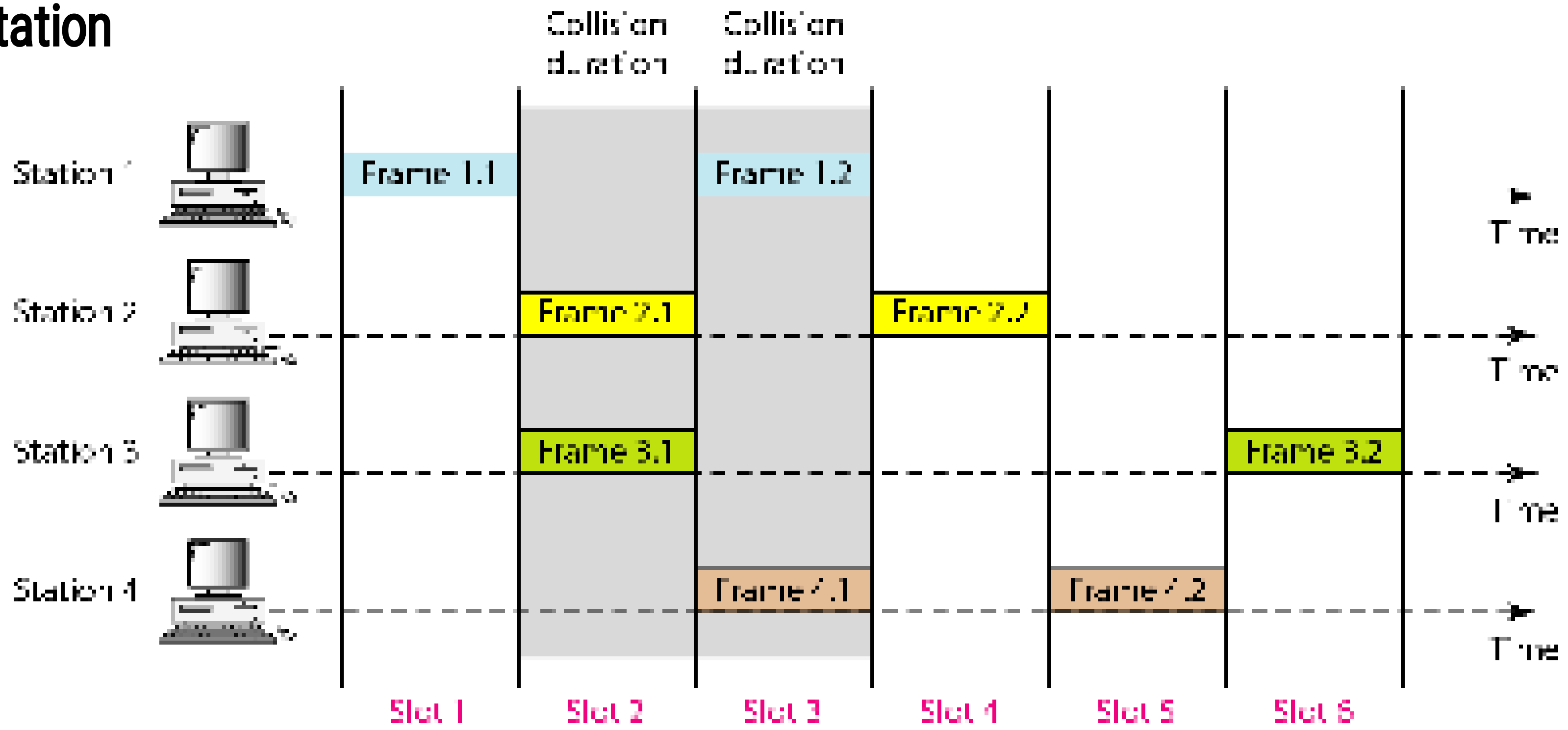
Example 12.3 (continued)

b. If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case $S = G \times e^{-2G}$ or $S = 0.184$ (18.4 percent). This means that the throughput is $500 \times 0.184 = 92$ and that only 92 frames out of 500 will probably survive. Note that this is the maximum throughput case, percentagewise.

c. If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this

Slotted ALOHA network

Divides time into slots of Tfr and forces the station to send at the begging of each station



Slotted ALOHA vulnerable time = Tfr *Throughput* $S = G \times e^{-G}$, $S_{max} = 0.368$ *when* $G=1$

Note

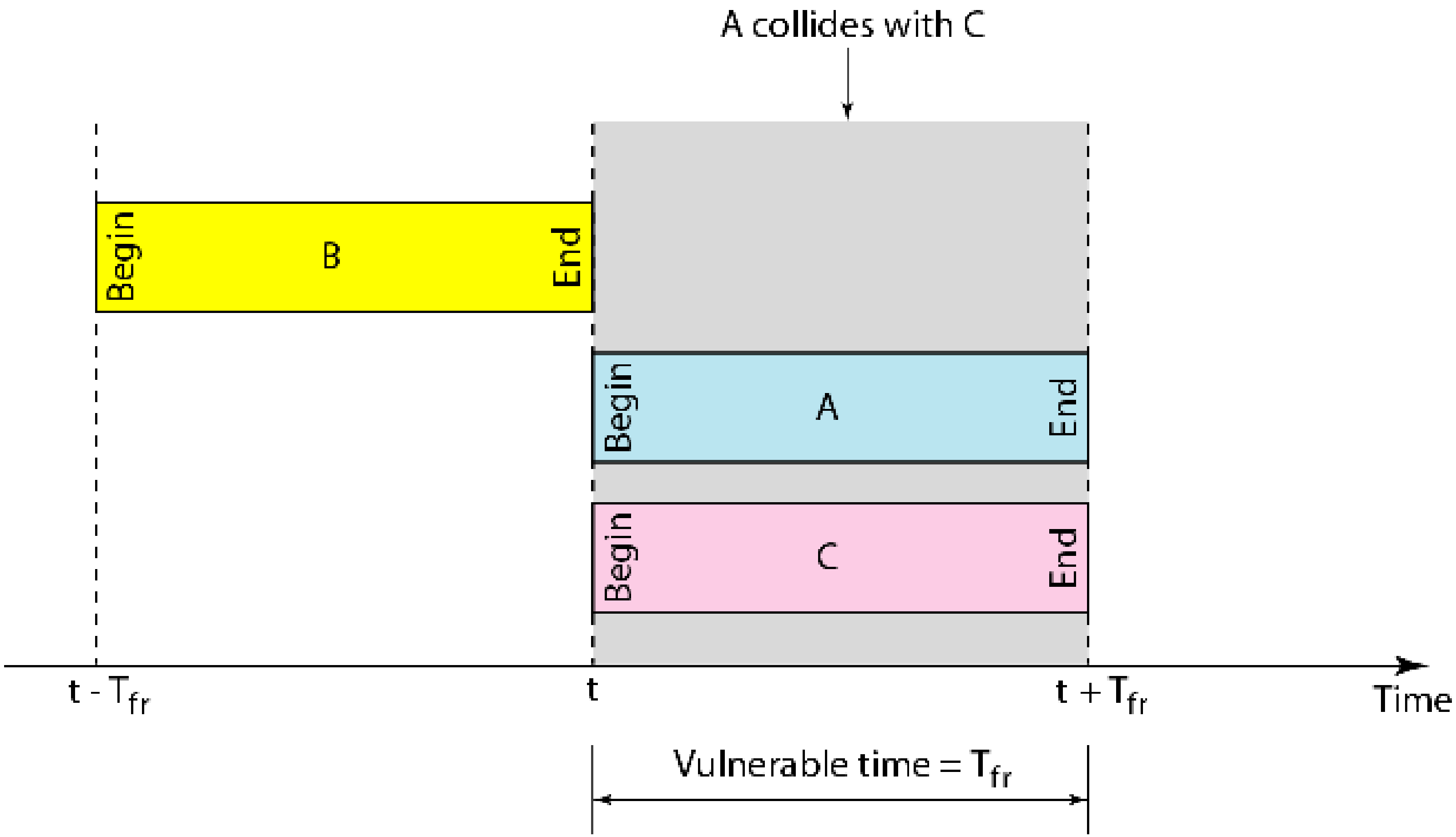
The throughput for slotted ALOHA is

$$S = G \times e^{-G}.$$

The maximum throughput

$S_{max} = 0.368$ when $G = 1$.

Figure 12.7 *Vulnerable time for slotted ALOHA protocol*



Example 12.4

A slotted ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces

a. 1000 frames per second   b. 500 frames per second

Solution

The frame transmission time is 200/200 kbps or 1 ms.

a. If the system creates 1000 frames per second, this is 1

frame per millisecond. The load is 1. In this case

$S = G \times e^{-G}$ or $S = 0.368$ (36.8 percent). This means

that the throughput is $1000 \times 0.0368 = 368$ frames.

Only 386 frames out of 1000 will probably survive.

Example 12.4 (continued)

b. If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case $S = G \times e^{-G}$ or $S = 0.303$ (30.3 percent). This means that the throughput is $500 \times 0.0303 = 151$. Only 151 frames out of 500 will probably survive.

c. If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this case $S = G \times e^{-G}$ or $S = 0.195$ (19.5 percent). This means that the throughput is $250 \times 0.195 = 49$. Only 49 frames out of 250 will probably survive.

Carrier Sense Multiple Access (CSMA)

- CSMA requires that each station first listens to the medium before sending.
- So it is based on the principle “sense before transmit”
- CSMA can reduce the possibility of collision , but it can not eliminate.
- This because of propagation delay.

Figure 12.8 *Space/time model of the collision in CSMA*

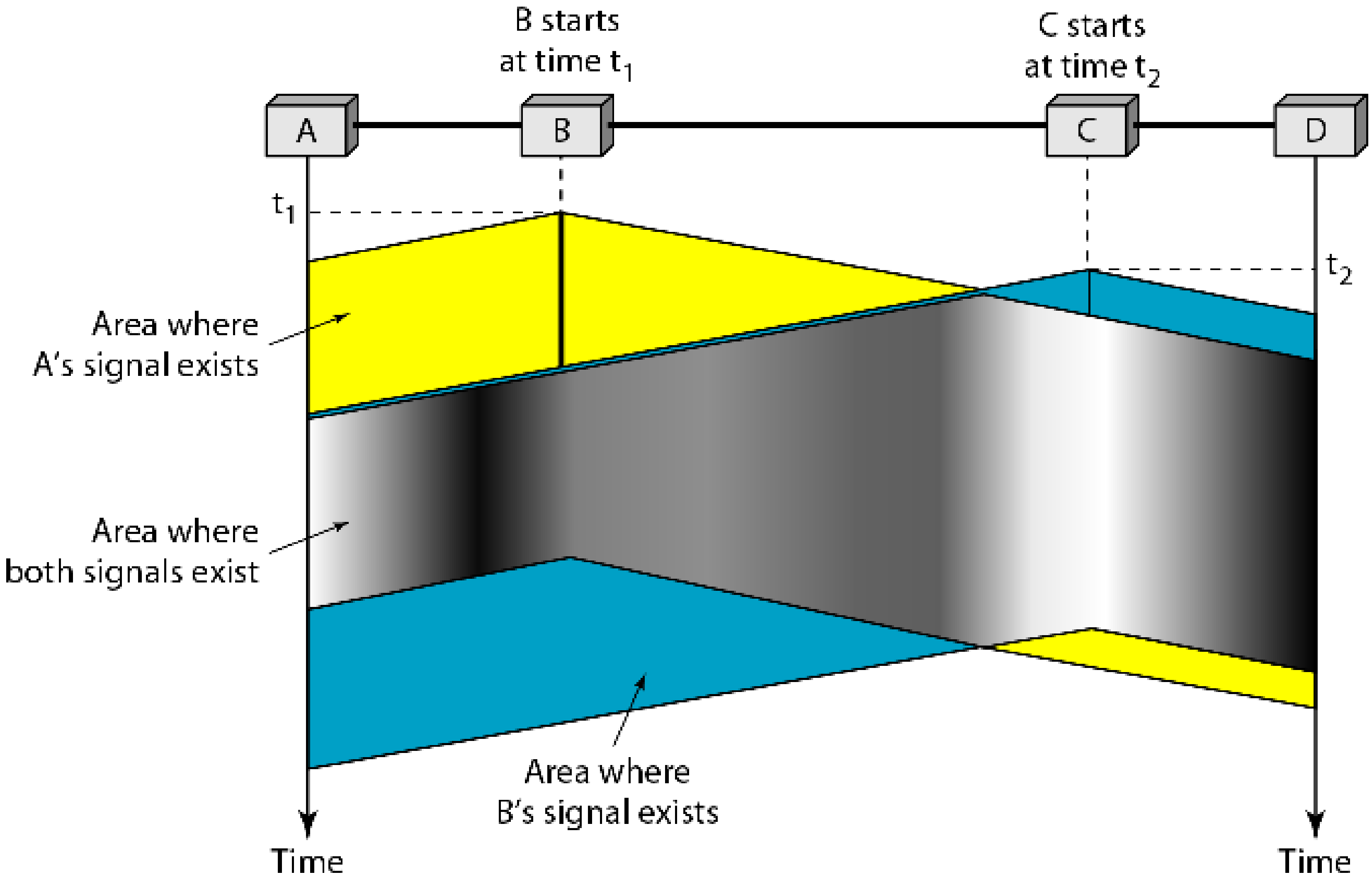
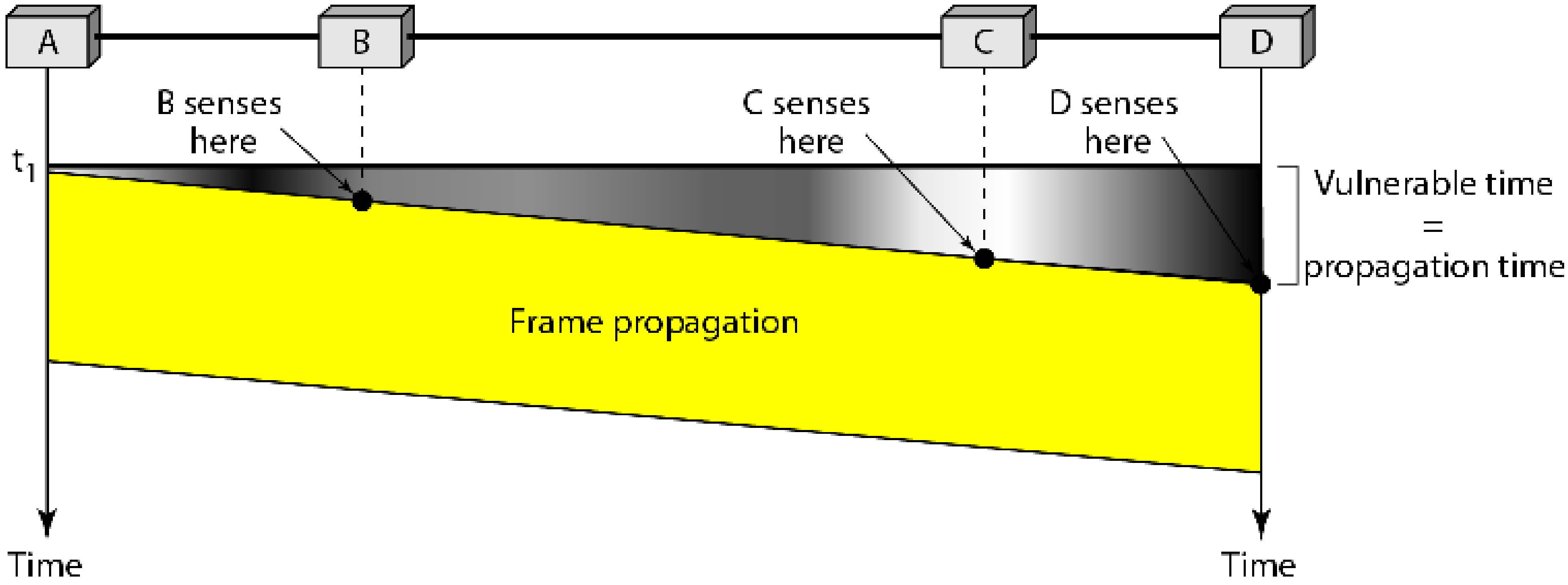


Figure 12.9 *Vulnerable time in CSMA*



Persistence methods :

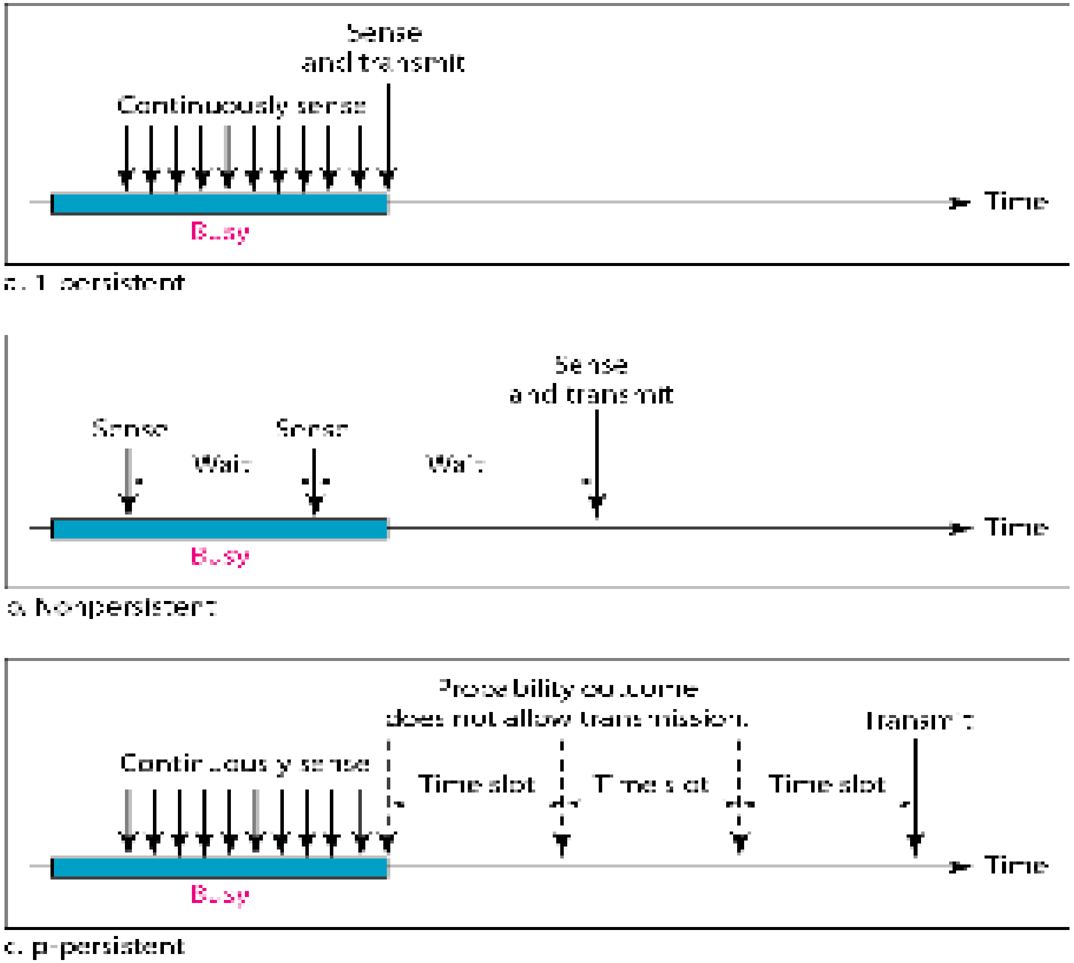
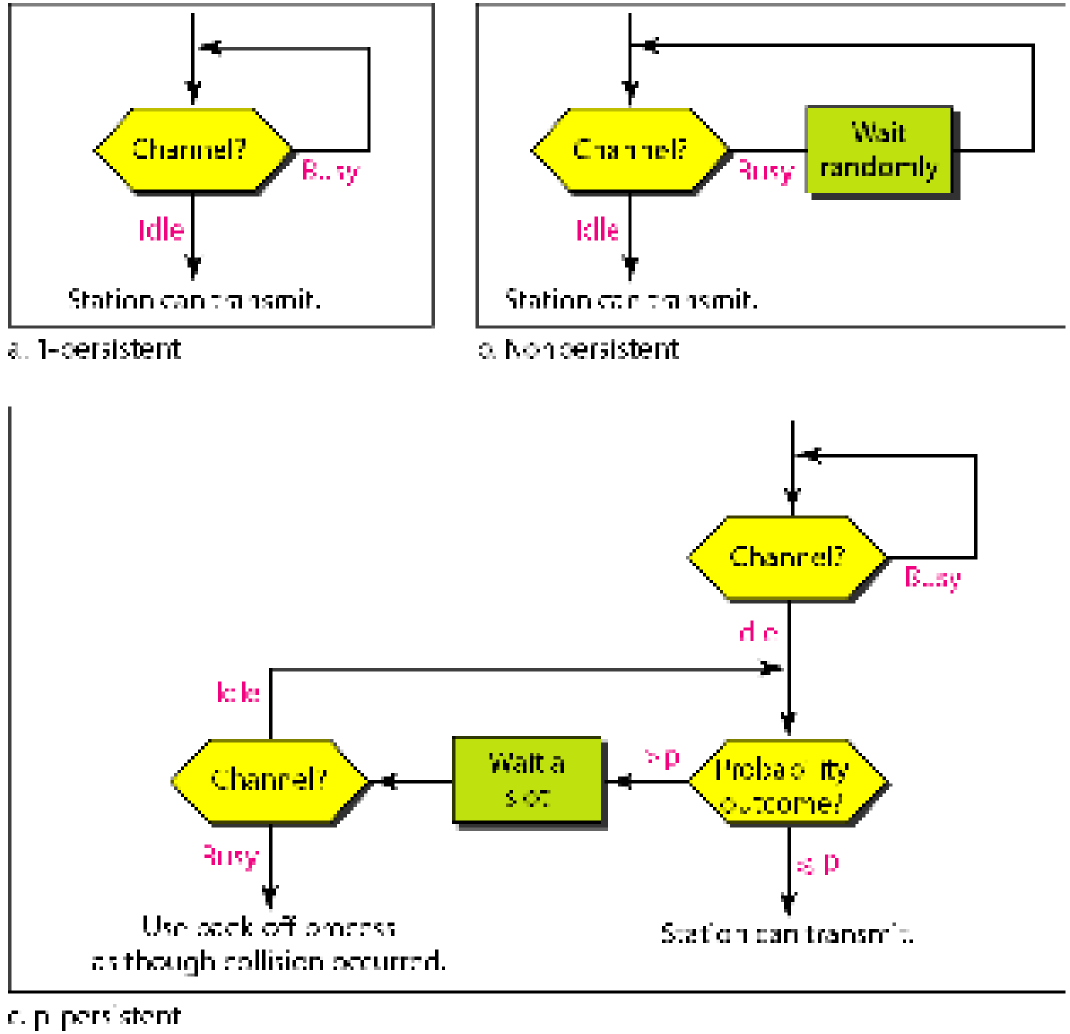


Figure 12.10 *Behavior of three persistence methods*

Figure 12.11 *Flow diagram for three persistence methods*



Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

- This protocol has a procedure to handle the collision.
- Stations see if transmission was successful. If so , the station is finished.

Otherwise the frame is sent again.

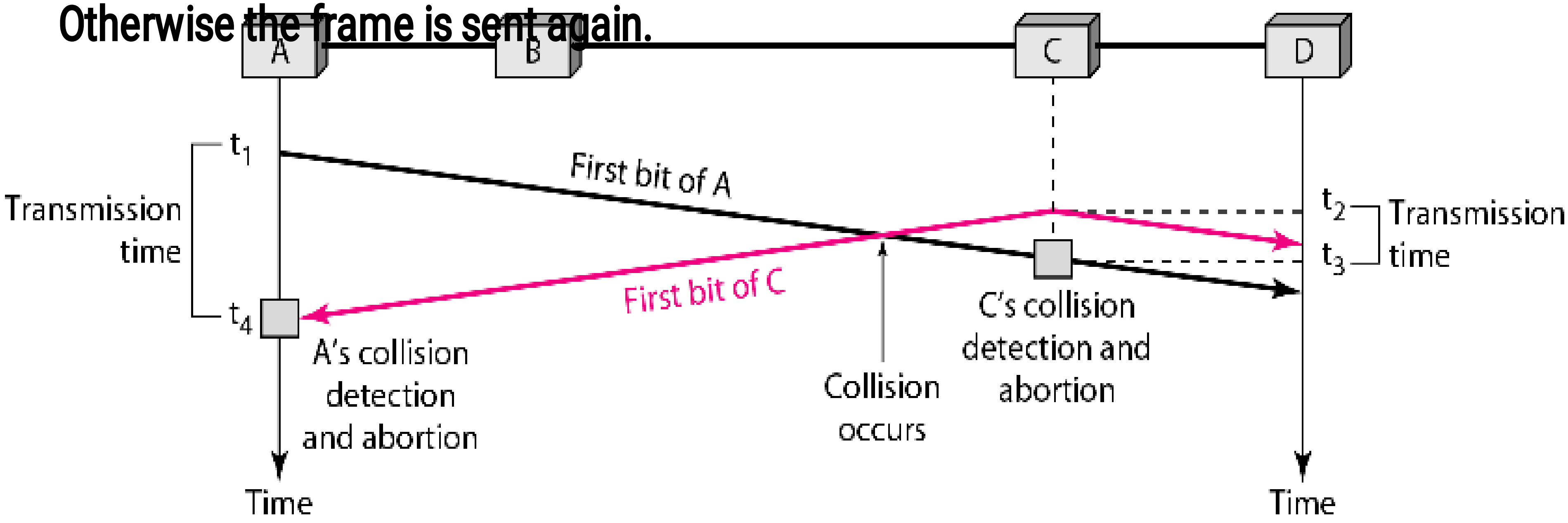


Figure 12.12 *Collision of the first bit in CSMA/CD*

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

Minimum frame size : The frame transmission time T_{fr} must be at least two times the maximum propagation time T_p.

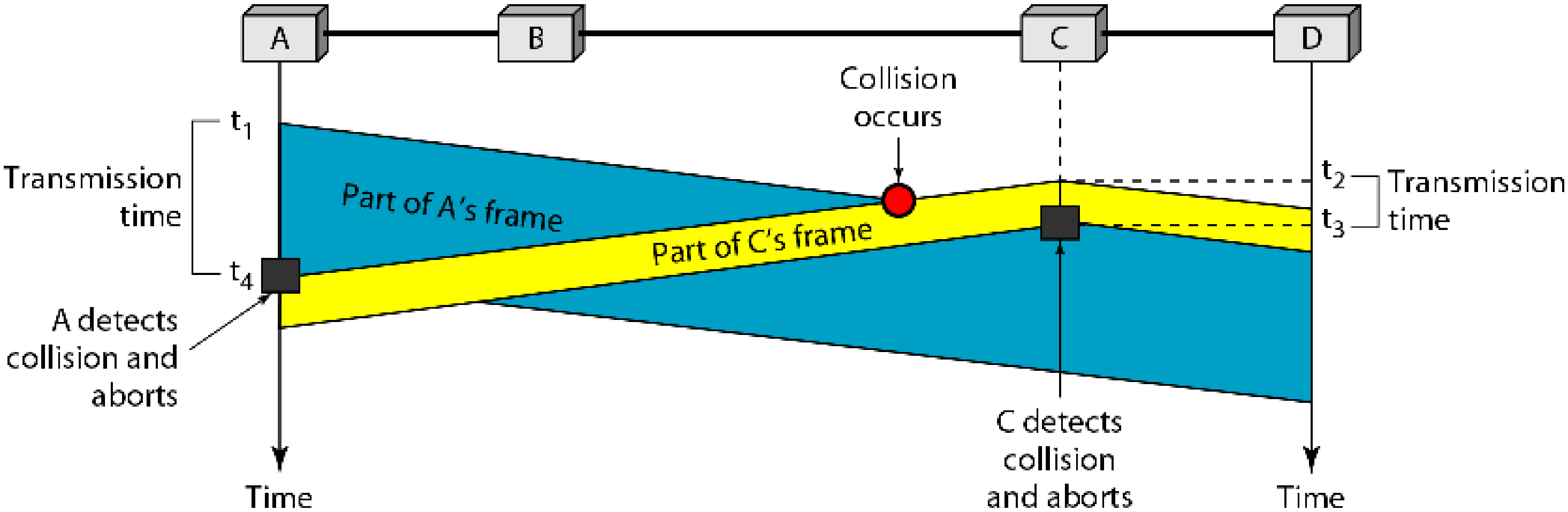


Figure 12.13 ***Collision and abortion in CSMA/CD***

Example 12.5

A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time (including the delays in the devices and ignoring the time needed to send a jamming signal, as we see later) is 25.6 μs, what is the minimum size of the frame?

Solution

The frame transmission time is $T_{fr} = 2 \times T_p = 51.2\ \mu s$. This means, in the worst case, a station needs to transmit for a period of 51.2 μs to detect the collision. The minimum size of the frame is 10 Mbps × 51.2 μs = 512 bits or 64 bytes. This is actually the minimum size of the frame for Standard Ethernet.

Figure 12.14 *Flow diagram for the CSMA/CD*

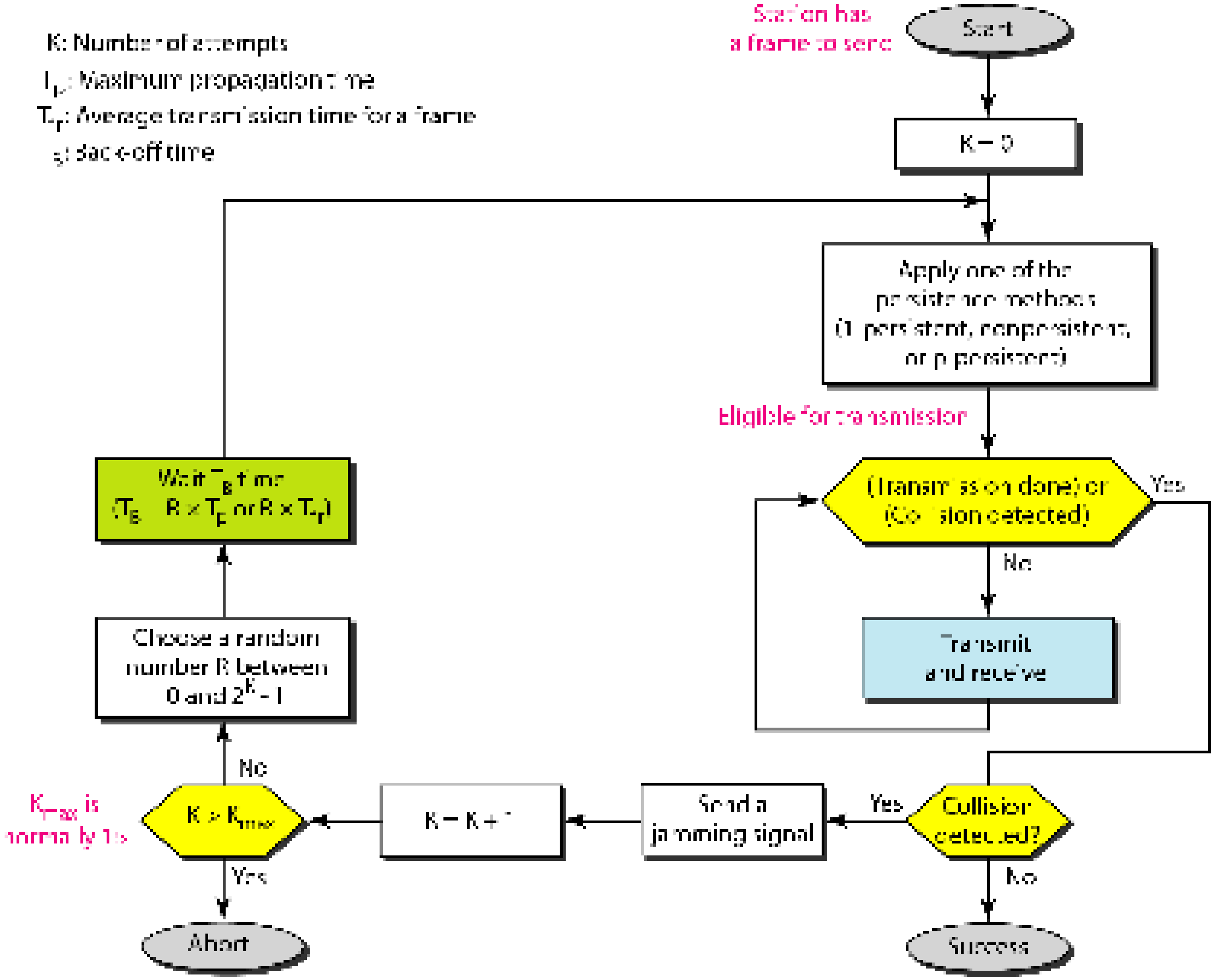
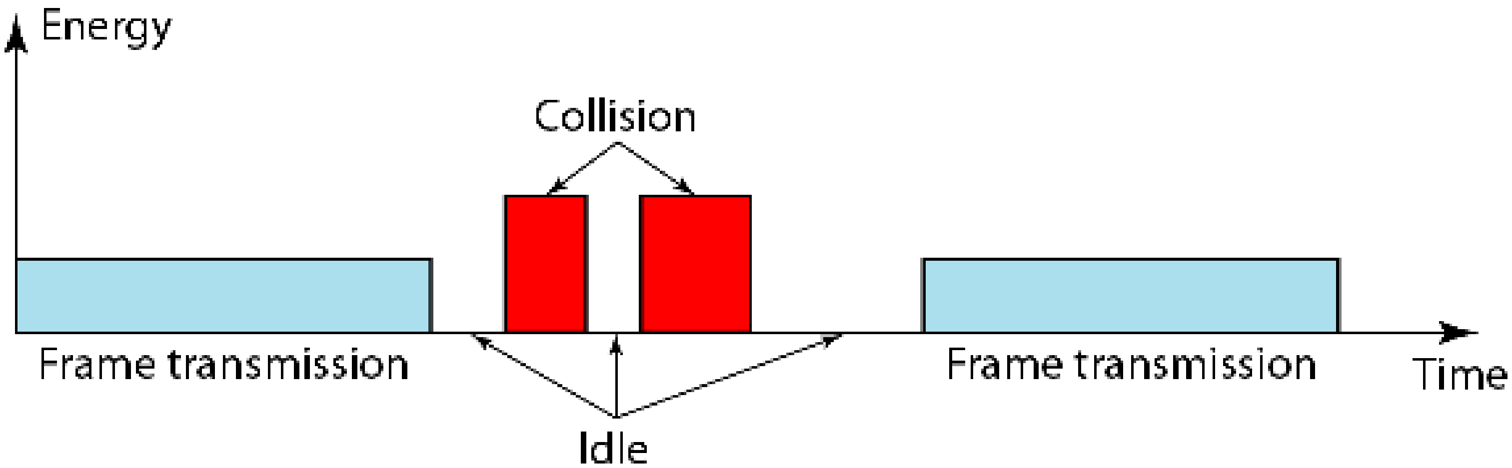
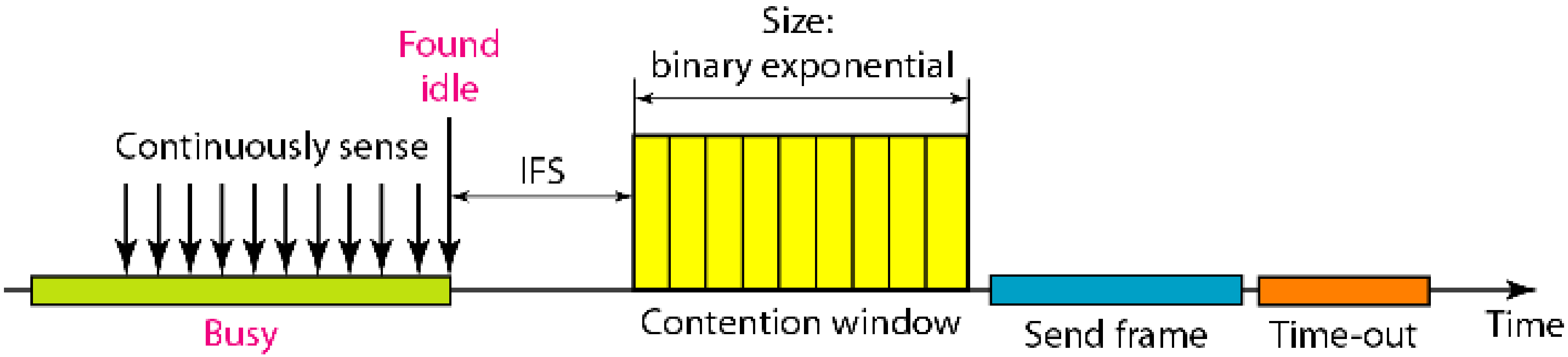


Figure 12.15 *Energy level during transmission, idleness, or collision*



***Throughput :** Throughput of CSMA/CD > pure or slotted ALOHA*

Figure 12.16 *Timing in CSMA/CA*



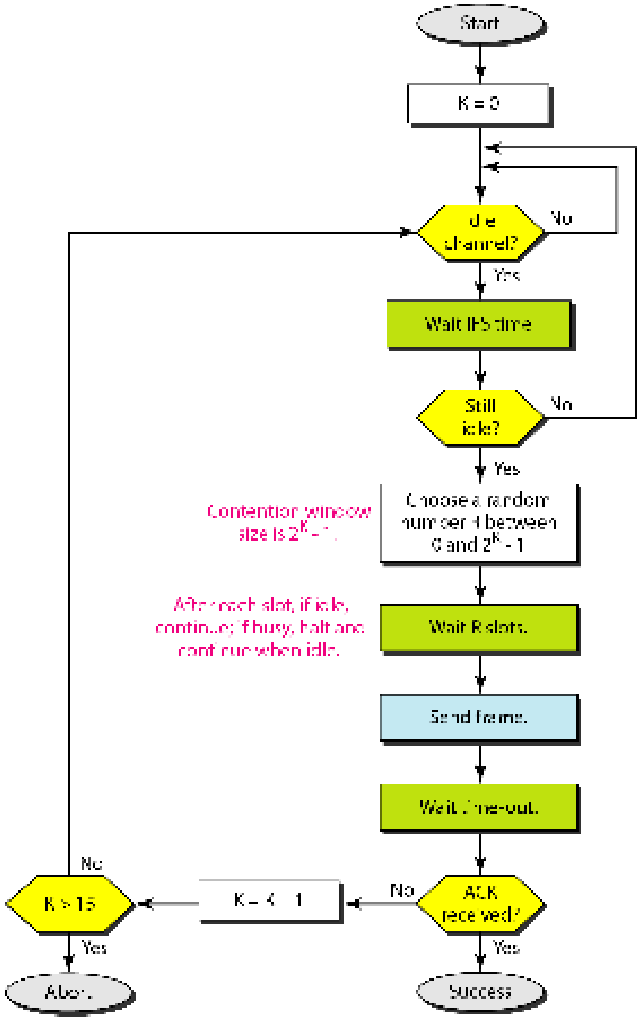
Note

In CSMA/CA, the IFS can also be used to define the priority of a station or a frame.

Note

In CSMA/CA, if the station finds the channel busy, it does not restart the timer of the contention window;
it stops the timer and restarts it when the channel becomes idle.

Figure 12.17 *Flow diagram for CSMA/CA*



12-2 CONTROLLED ACCESS

In controlled access, the stations consult one another to find which station has the right to send. A station cannot send unless it has been authorized by other stations. We discuss three popular controlled-access methods.

Topics discussed in this section:

Reservation
Polling
Token Passing

Figure 12.18 *Reservation access method*

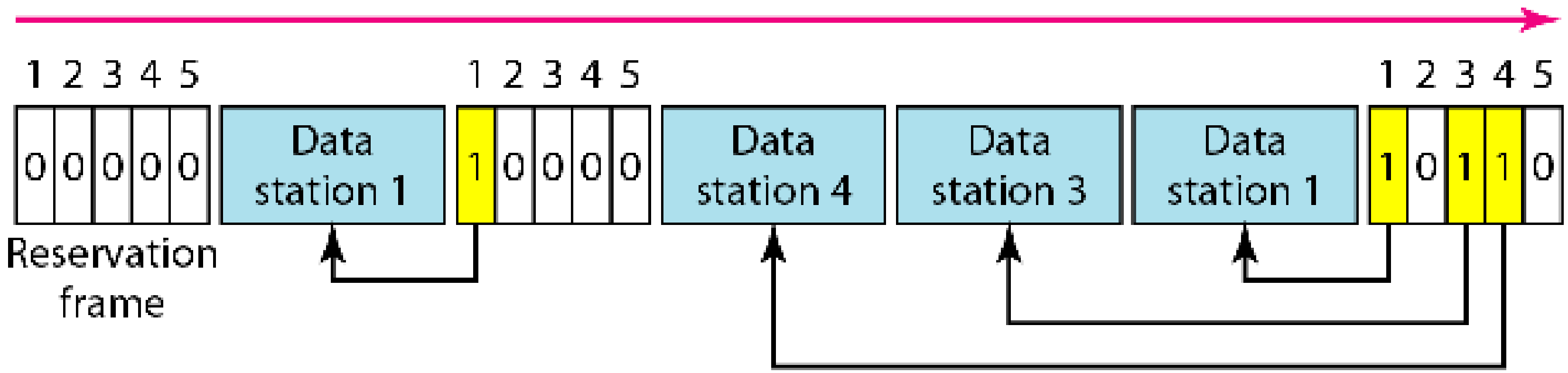


Figure 12.19 *Select and poll functions in polling access method*

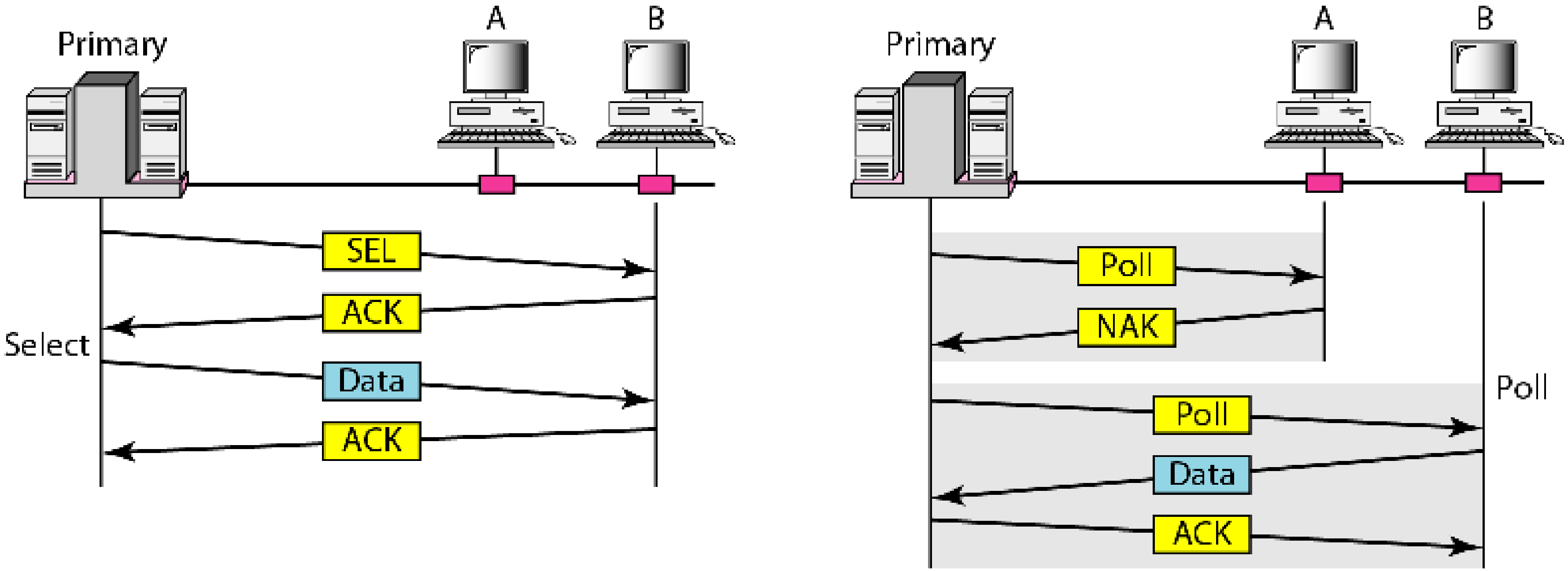
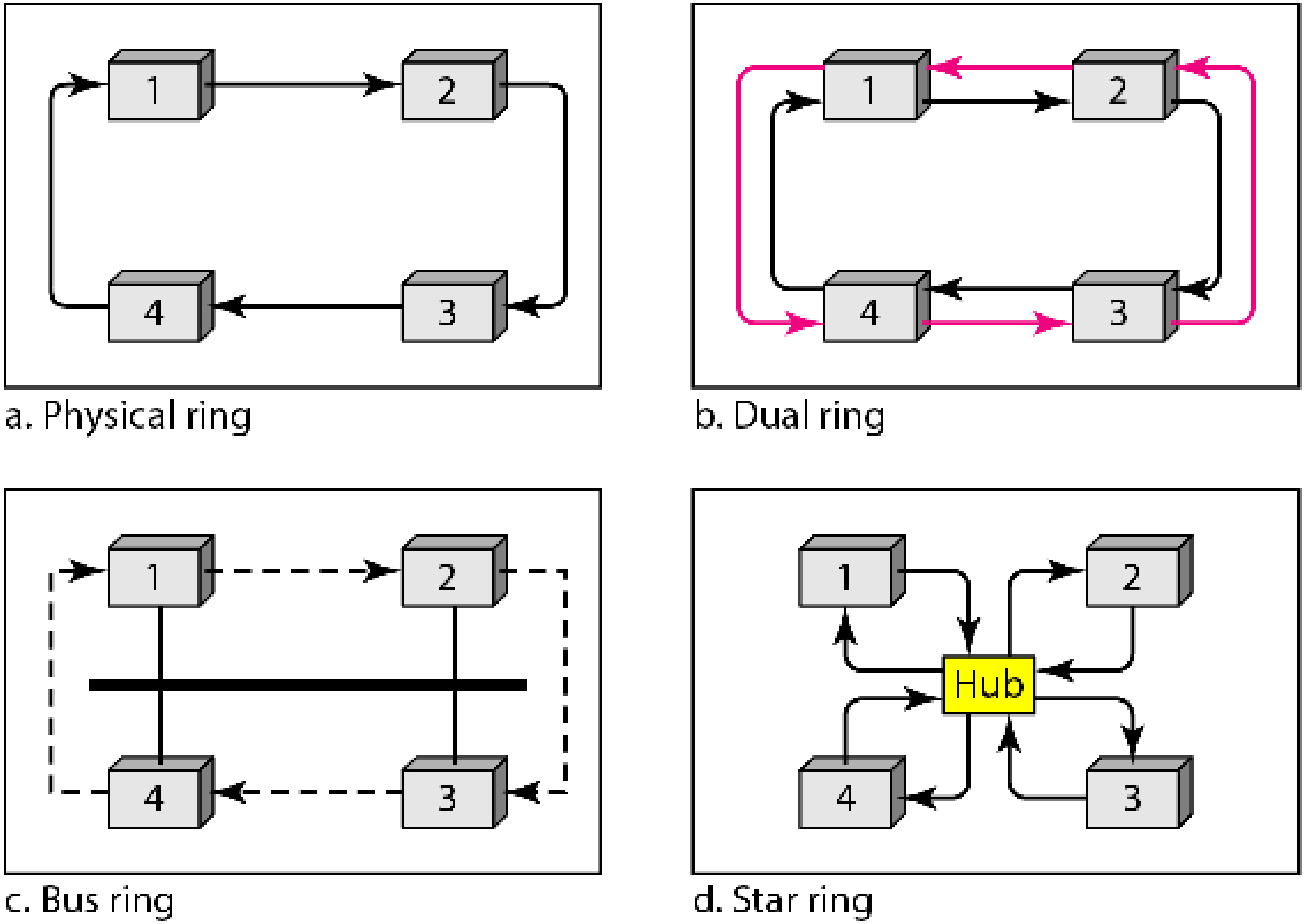


Figure 12.20 *Logical ring and physical topology in token-passing access method*



12-3 CHANNELIZATION

***Channelization** is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.*

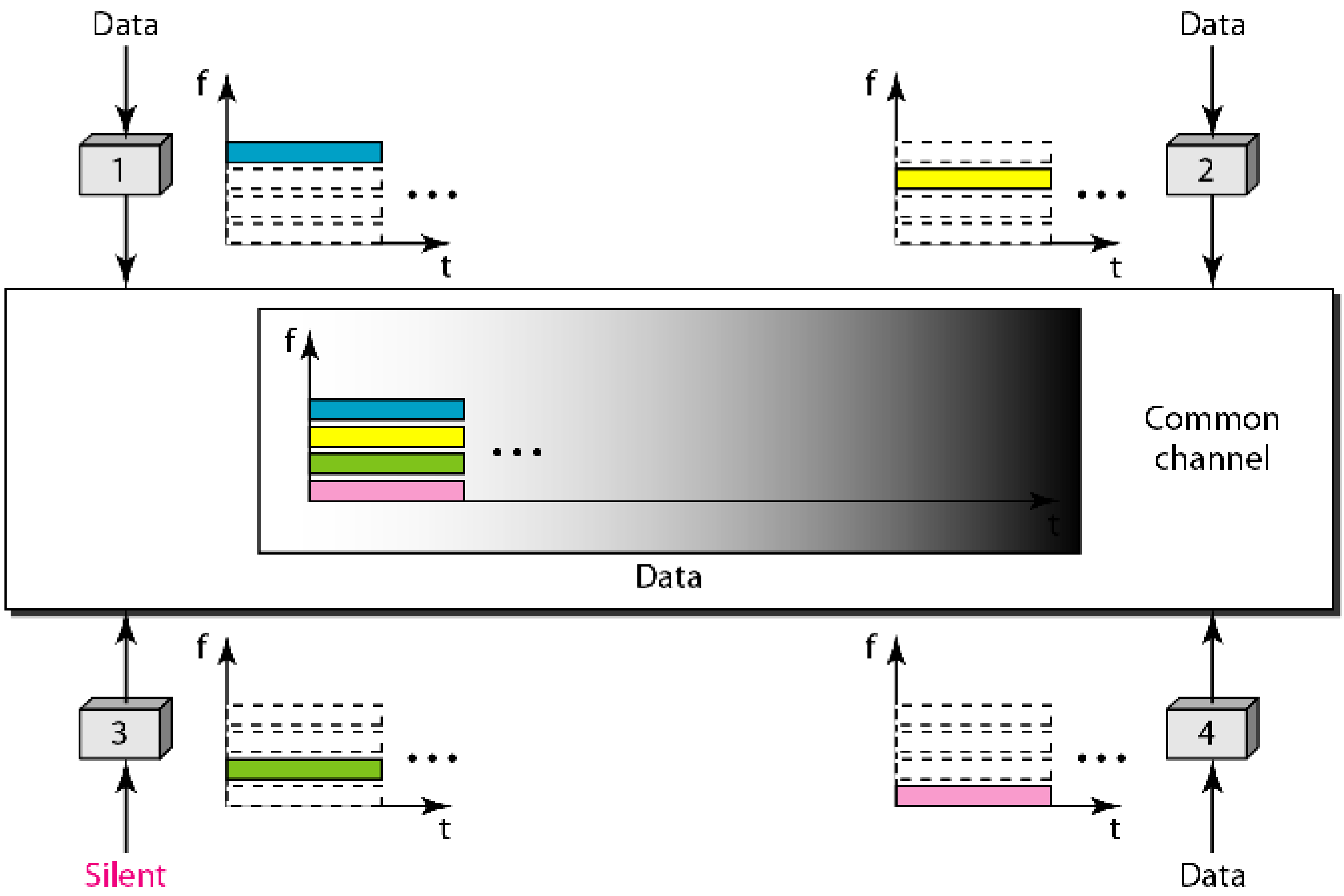
Topics discussed in this section:

Frequency-Division Multiple Access (FDMA)
Time-Division Multiple Access (TDMA)
Code-Division Multiple Access (CDMA)

Note

We see the application of all these methods in Chapter 16 when we discuss cellular phone systems.

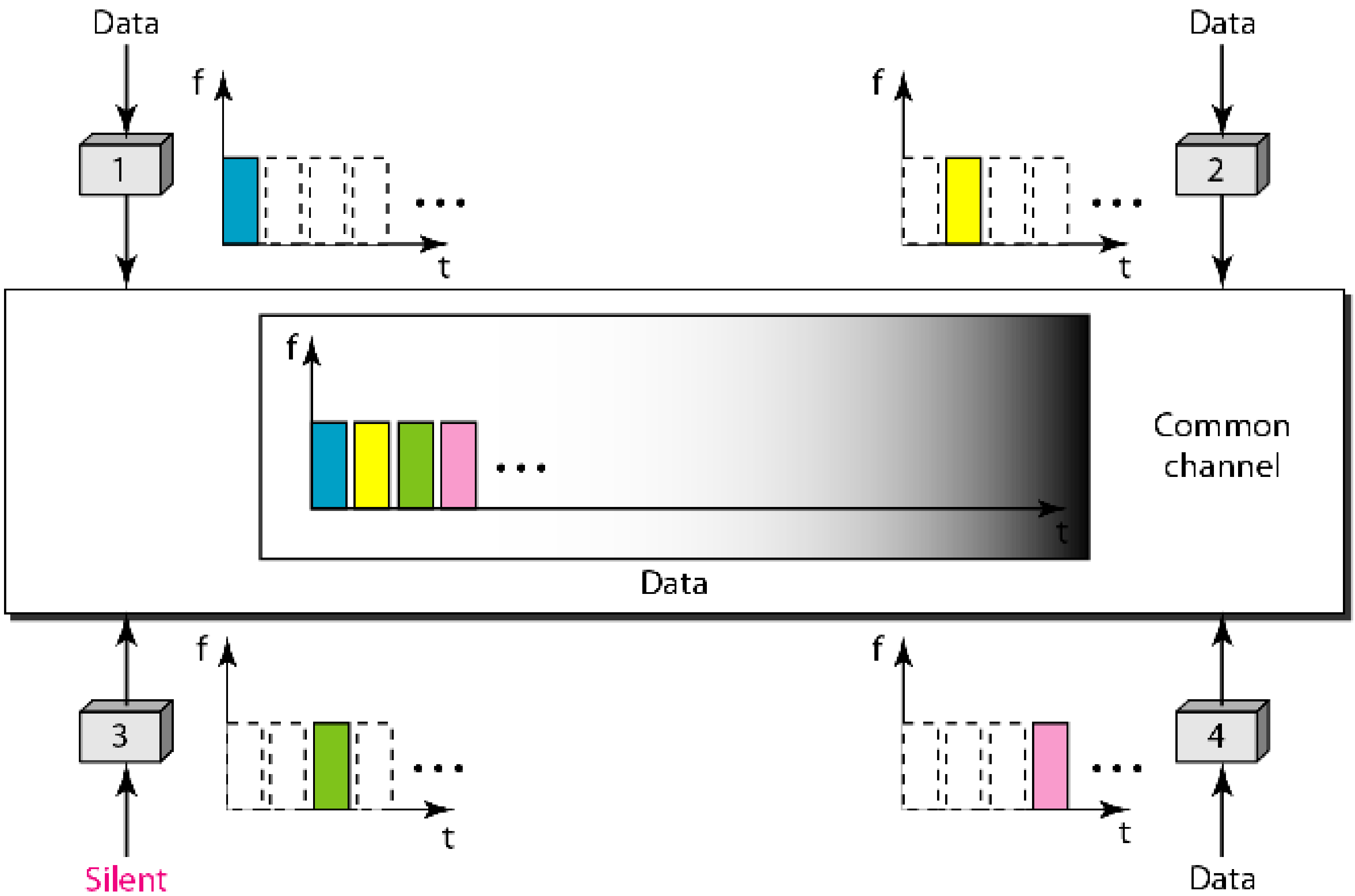
Figure 12.21 *Frequency-division multiple access (FDMA)*



Note

In FDMA, the available bandwidth of the common channel is divided into bands that are separated by guard bands.

Figure 12.22 *Time-division multiple access (TDMA)*



Note

In TDMA, the bandwidth is just one channel that is timeshared between different stations.

Note

In CDMA, one channel carries all transmissions simultaneously.

Figure 12.23 *Simple idea of communication with code*

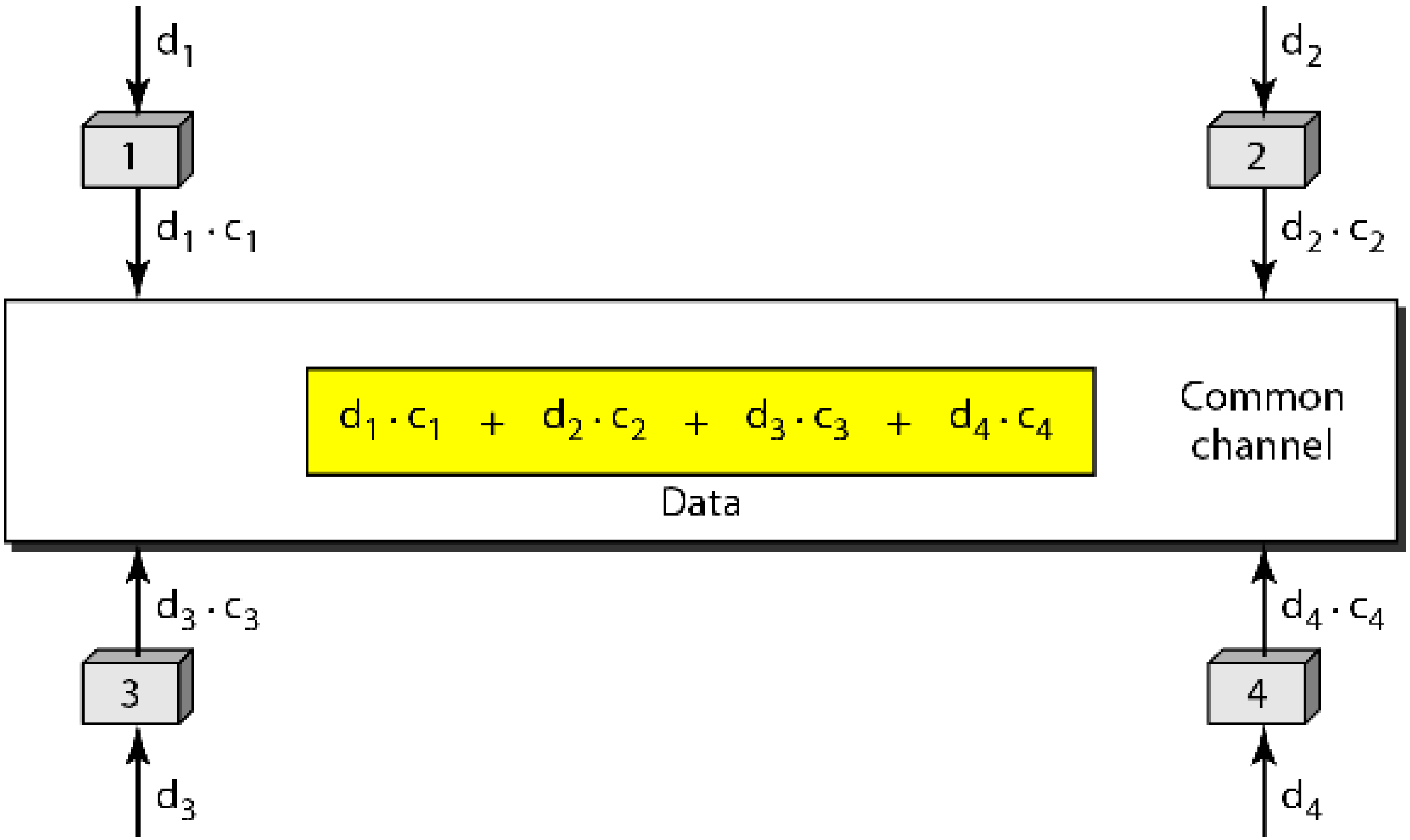


Figure 12.24 *Chip sequences*

C_1	C_2	C_3	C_4
[+1 +1 +1 +1]	[+1 -1 +1 -1]	[+1 +1 -1 -1]	[+1 -1 -1 +1]

Figure 12.25 *Data representation in CDMA*

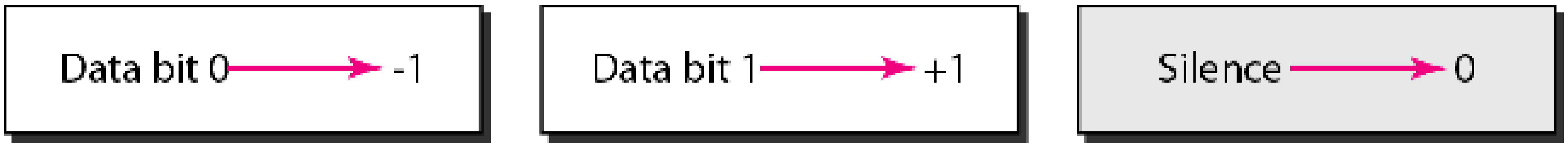


Figure 12.26 *Sharing channel in CDMA*

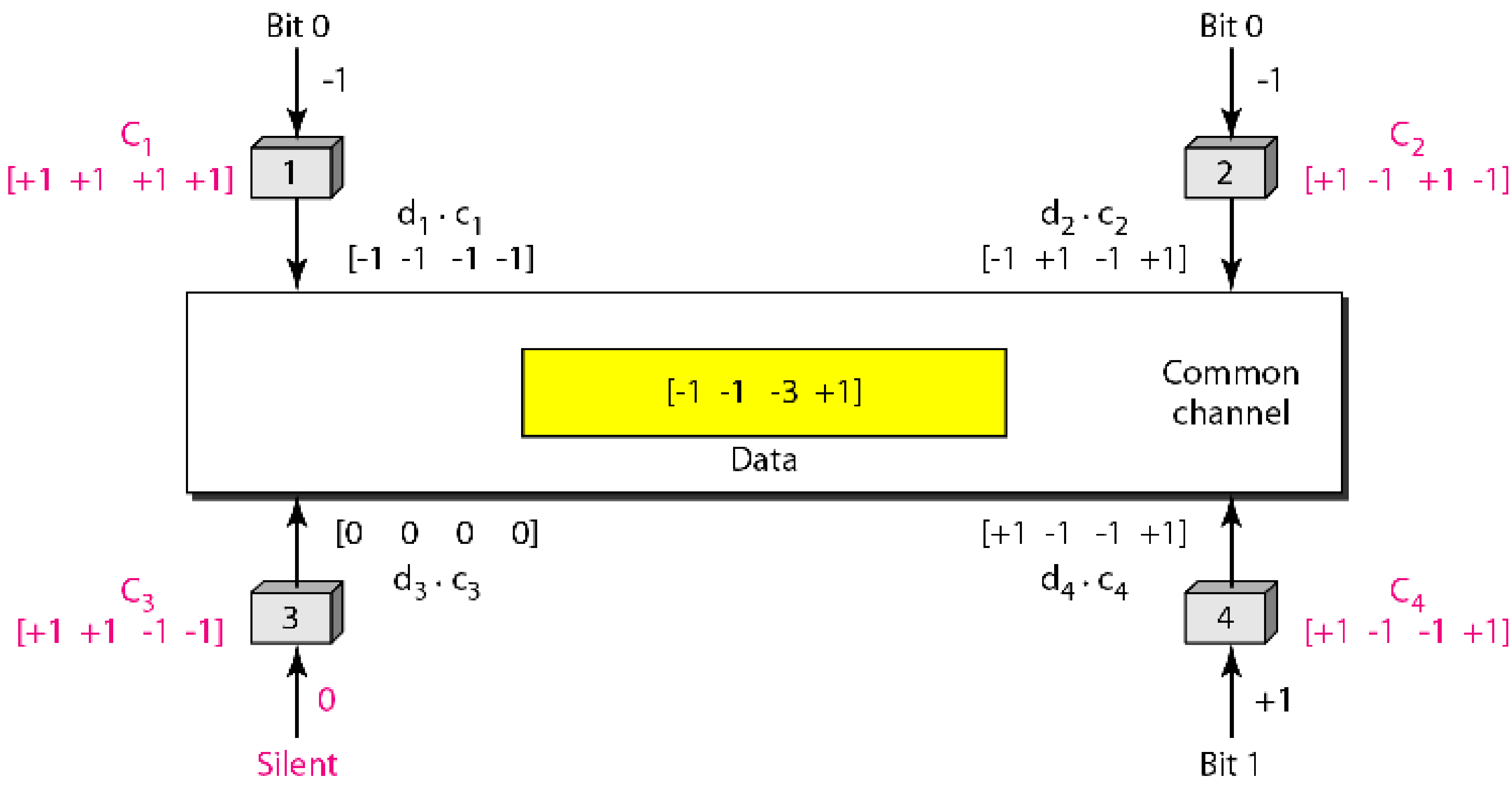


Figure 12.27 *Digital signal created by four stations in CDMA*

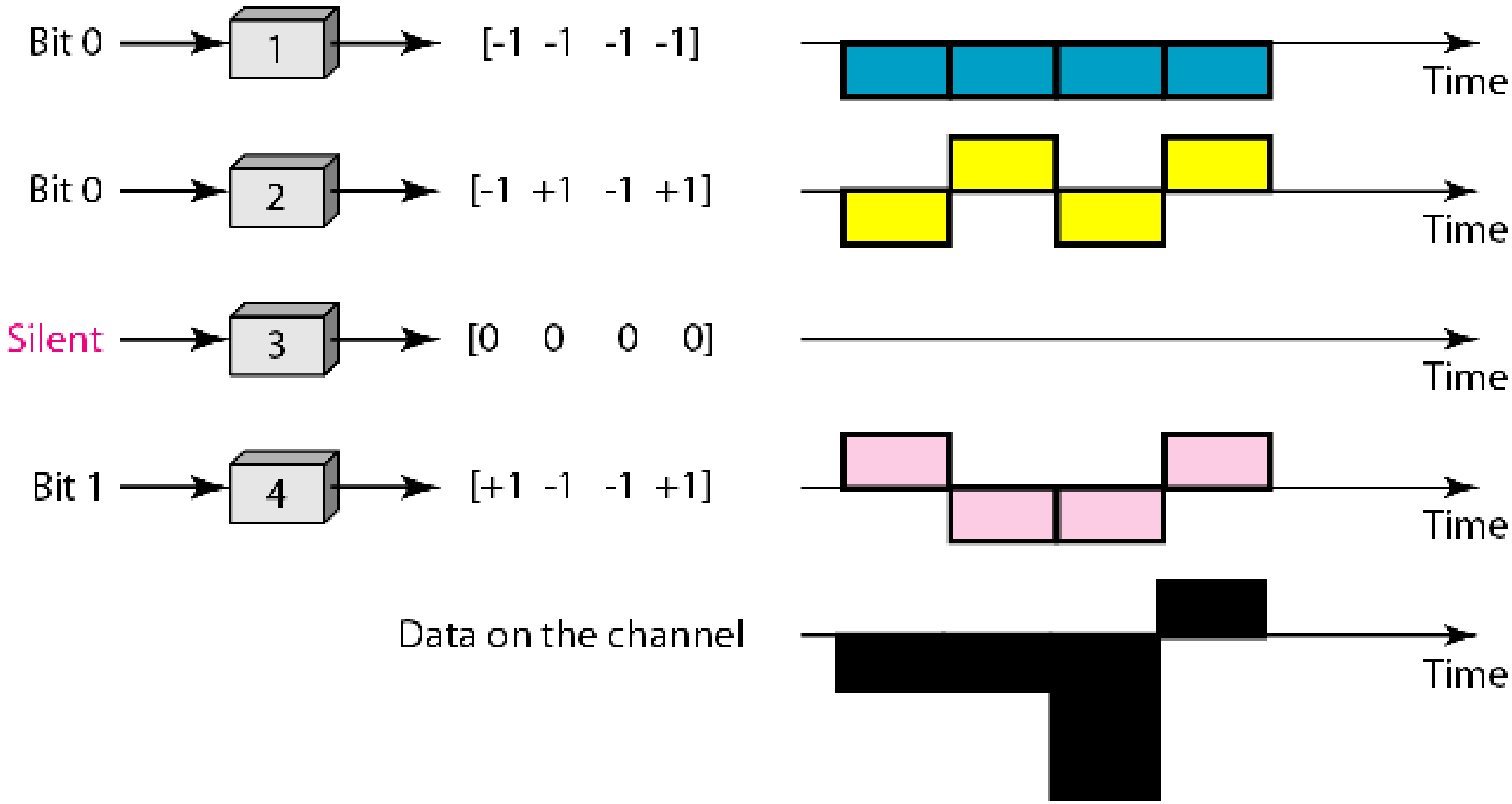


Figure 12.28 *Decoding of the composite signal for one in CDMA*

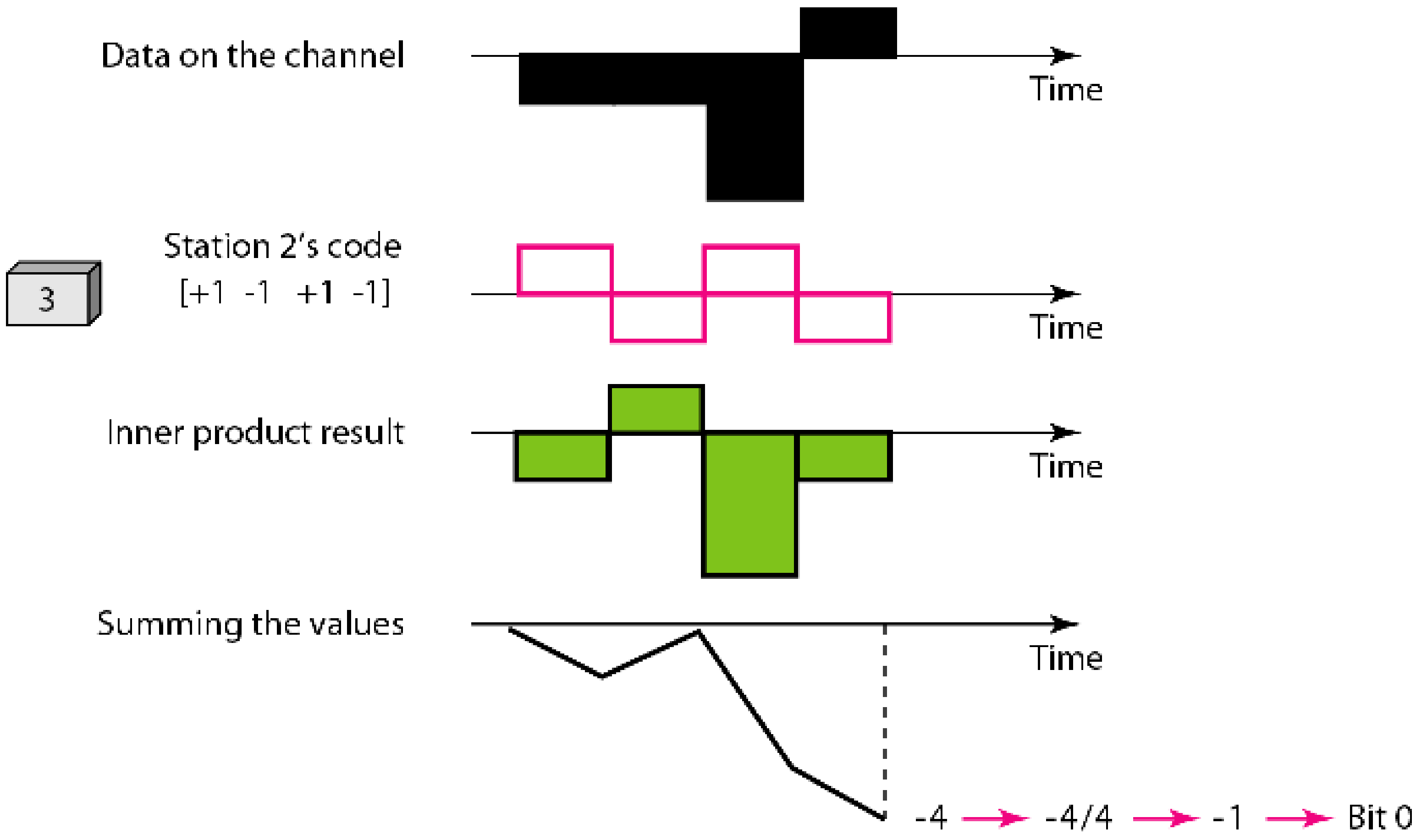


Figure 12.29 *General rule and examples of creating Walsh tables*

$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

a. Two basic rules

$$W_1 = \begin{bmatrix} +1 \end{bmatrix}$$

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} \qquad W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

b. Generation of W_1, W_2, and W_4

Note

The number of sequences in a Walsh table needs to be $N = 2^m$.

Example 12.6

Find the chips for a network with
a. Two stations *b. Four stations*

Solution

We can use the rows of W_2 and W_4 in Figure 12.29:

a. For a two-station network, we have

[+1 +1] and [+1 −1].

b. For a four-station network we have

[+1 +1 +1 +1], [+1 −1 +1 −1],
[+1 +1 −1 −1], *and* [+1 −1 −1 +1].

Example 12.7

What is the number of sequences if we have 90 stations in our network?

Solution

The number of sequences needs to be 2^m. We need to choose m = 7 and N = 2^7 or 128. We can then use 90 of the sequences as the chips.

Example 12.8

Prove that a receiving station can get the data sent by a specific sender if it multiplies the entire data on the channel by the sender's chip code and then divides it by the number of stations.

Solution

Let us prove this for the first station, using our previous four-station example. We can say that the data on the channel

$$D = (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4).$$

The receiver which wants to get the data sent by station 1 multiplies these data by c_1.

Example 12.8 (continued)

$$\begin{aligned}
D \cdot c_1 &= (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4) \cdot c_1 \\
&= d_1 \cdot c_1 \cdot c_1 + d_2 \cdot c_2 \cdot c_1 + d_3 \cdot c_3 \cdot c_1 + d_4 \cdot c_4 \cdot c_1 \\
&= d_1 \times N + d_2 \times 0 + d_3 \times 0 + d_4 \times 0 \\
&= d_1 \times N
\end{aligned}$$

When we divide the result by N, we get d_1.